# Structural Anomalies Detected in Ceramic Matrix Composites Using Combined Nondestructive Evaluation and Finite Element Analysis (NDE and FEA)

Most reverse engineering approaches involve imaging or digitizing an object and then creating a computerized reconstruction that can be integrated, in three dimensions, into a particular design environment. The rapid prototyping technique builds high-quality physical prototypes directly from computer-aided design files. This fundamental technique for interpreting and interacting with large data sets is being used here via Velocity^2 (an integrated image-processing software, ref. 1) using computed tomography (CT) data to produce a prototype three-dimensional test specimen model for analyses.

A study at the NASA Glenn Research Center proposes to use these capabilities to conduct a combined nondestructive evaluation (NDE) and finite element analysis (FEA) to screen pretest and posttest structural anomalies in structural components. A tensile specimen made of silicon nitrite (Si_3N_4) ceramic matrix composite was considered to evaluate structural durability and deformity. Ceramic matrix composites are being sought as candidate materials to replace nickel-base superalloys for turbine engine applications. They have the unique characteristics of being able to withstand higher operating temperatures and harsh combustion environments. In addition, their low densities relative to metals help reduce component mass (ref. 2).

Detailed three-dimensional volume rendering of the tensile test specimen was successfully carried out with Velocity^2 (ref. 1) using two-dimensional images that were generated via computed tomography. Subsequent, three-dimensional finite element analyses were performed, and the results obtained were compared with those predicted by NDE-based calculations and experimental tests. It was shown that Velocity^2 software can be used to render a three-dimensional object from a series of CT scan images with a minimum level of complexity. The analytical results (ref. 3) show that the high-stress regions correlated well with the damage sites identified by the CT scans and the experimental data. Furthermore, modeling of the voids collected via NDE offered an analytical advantage that resulted in more accurate assessments of the material's structural strength. The top figure shows a CT scan image of the specimen test section illustrating various hidden structural entities in the material and an optical image of the test specimen considered in this study. The bottom figure represents the stress response predicted from the finite element analyses (ref .3) for a selected CT slice where it clearly illustrates the correspondence of the high stress risers due to voids in the material with those predicted by the NDE. This study is continuing, and efforts are concentrated on improving the modeling capabilities to imitate the structural anomalies as detected.
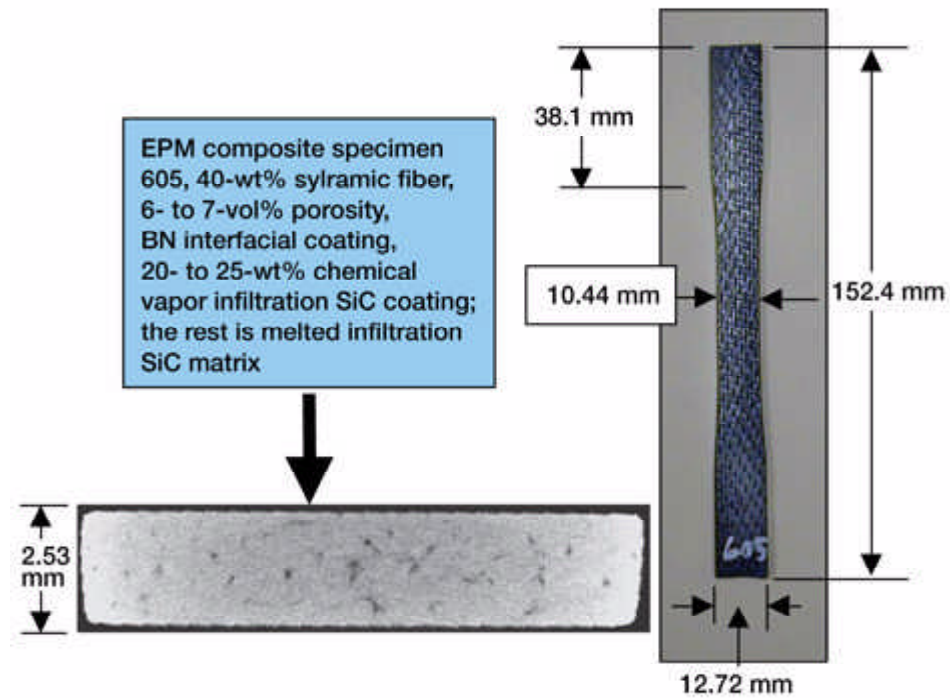
Ceramic matrix composite tensile specimen, showing dimensions, and a selected CT slice. Left: CT image. Right: Enabling propulsion material (EPM) specimen 605.
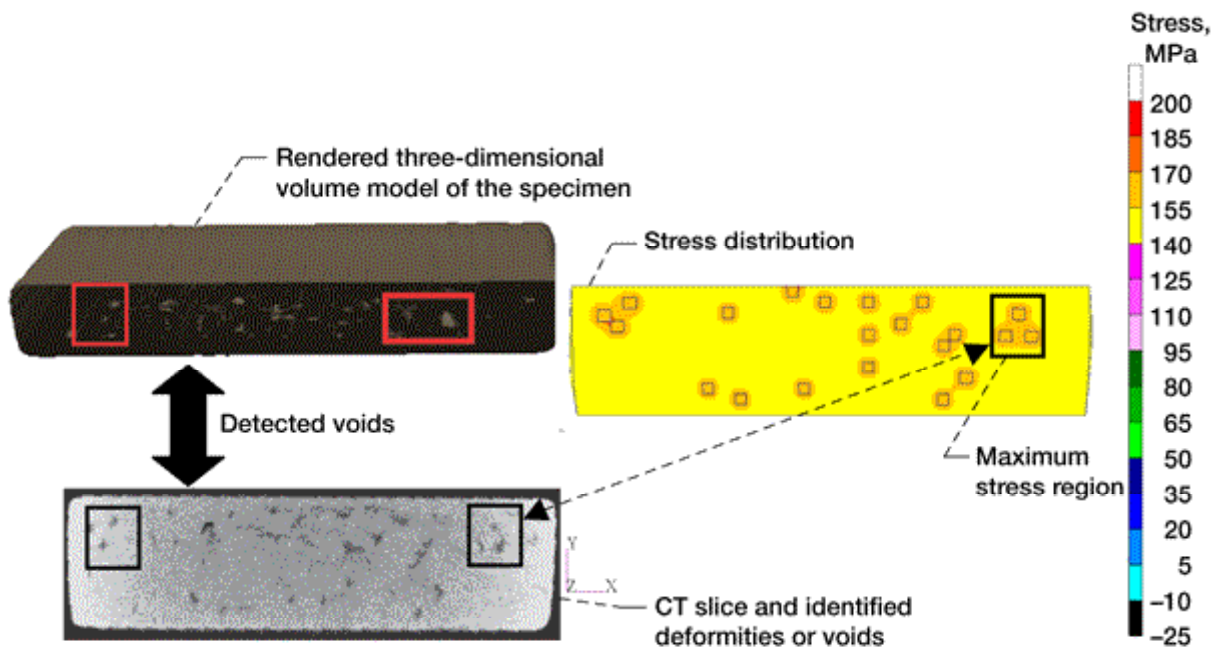
A matching section of a three-dimensional volume NDE-generated model and a CT image slice with a three-dimensional finite element result showing the stress state under tensile loading conditions.

References

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Cleveland State University contact: Dr. Ali Abdul-Aziz, 216-433-6729, Fax 216-977-7150, Ali.Abdul-aziz@grc.nasa.gov
Glenn contact: Dr. George Baaklini, 216-433-6016, Fax 216-977-7150, George.Y.Baaklini@nasa.gov
U.S. Army, Vehicle Technology Directorate at Glenn contact: Dr. Ramakrishna Bhatt, 216-433-5513, Fax 216-977-7150, Ramakrishna.T.Bhatt@grc.nasa.gov
Authors: Dr. Ali Abdul-Aziz, Dr. George Y. Baaklini, Dr. Ramakrishna T. Bhatt
Headquarters program office: OAT
Programs/Projects: HOTPC